

**Project Status Report for:** May 2000**Project Title:** Ultra Low NO<sub>x</sub> Integrated System for Coal-Fired Power Plants**Project Number:** 91890460 **Program Manager:** John Marion**Customer Name:** U.S. DOE / Performance Projects **Project Leader:** Charles Maney**GOALS AND OBJECTIVES:**

**Develop low cost, retrofit NO<sub>x</sub> control technologies to address current and anticipated, near term emissions control legislation for existing coal fired utility boilers. Specific goals include:**

- Achieve < 0.15 lb/MMBtu NO<sub>x</sub> for eastern bituminous coals
- Achieve < 0.10 lb/MMBtu NO<sub>x</sub> for western sub-bituminous or lignitic coals
- Achieve economics at least 25% less than SCR-only technology
- Validate NO<sub>x</sub> control technology through large (15 MWt) pilot scale demonstration
- Evaluate the engineering feasibility and economics for representative plant cases
- Provide input to develop commercial guidelines for specified equipment
- Provide input to develop a commercialization plan for the resultant technologies

**WORK PLANNED FROM PREVIOUS REPORT:****Task 2.1 – Test Fuels Characterization**

- The test fuels (one bituminous and one subbituminous) will be identified in May as part of the initial Advisory Panel meeting.

**Task 2.2 – Low NO<sub>x</sub> Pyrolysis Burners**

- A draft layout of the main windbox compartment nozzles arrangement and separated overfire air elevations for use in the large pilot scale testing will be generated in May.

**Task 2.3 – Global Mixing Process Improvement**

- Evaluation of the ~~two~~ reduced run time modeling approaches will be completed in May. In addition, the SOFA modeling matrix will be finalized and parametric case runs initiated.

**Task 2.4 – Advanced Control System Design**

- Secondary ~~approaches~~ approaches to obtain data for neural net model development will be investigated
- Continue MatLab / Simulink air and fuel flow balancing controller modeling
- Complete engineering design of fuel and air flow control system for large pilot scale testing
- Procure carbon in ash sensor system materials

**Task 3.1 – Test Planning & Facility Preparation**

- Pursuant to ~~Milestone~~ #5, General Test Facility Preparation, check-out of the BSF plumbing / mechanical and ~~electrical~~ systems will be completed in May. Planned work includes:

### Plumbing / Mechanical

- Remove rust accumulation from the BSF hopper bottom,
- Complete the integrity testing of the "V – Hopper,"
- Refurbish waterbed compartments,
- Remove, clean, & lubricate the 18" secondary air windbox dampers,
- De-scale the windbox plenums & compartment ducting,
- Inspect and lubricate main windbox compartment dampers,
- De-slag BSF water jacket ports for next "hydo-test,"
- Initiate the replacement of the superheater division panel tubes,
- Inspect the main secondary air flow ducting (FD fan to BSF),
- Inspect all air & water utility plumbing systems,
- Inspect the coal transport lines,
- Cleaning the coal feeder (Thayer) & housing in preparation for future maintenance,

### Electrical

- Test individual DCS I/O blocks,
- Test main power circuits to BSF / related equipment,
- Inspect / operate electronic dampers (air heater, and secondary air flow control)
- Inspect / operate facility fans (FD & ignitor)
- Schedule vendor for direct fired air heater (Maxon), coal feeder (Thayer) and soot blower maintenance / check-out

### Task 4 – Carbon Burnout System Evaluation

- The field unit for CBO™ cost / performance evaluation will be selected. In addition, preliminary CBO™ cost and performance data will be transferred from Progress Materials to CE.

### Task 5 – Engineering Systems Analysis & Economics

- Continued development of a preliminary cost comparison between various low NO<sub>x</sub> control systems will be performed. Design parameters for the systems will be developed. Methodology for economic analyses will be proposed.

### Task 6 – Advisory Panel

- The first advisory panel meeting will be held in Windsor, CT on May 24, 2000.

**ACCOMPLISHMENTS FOR REPORTING PERIOD:****Task 2.1 – Test Fuels Characterization**

- The test fuels (one bituminous and one subbituminous) will be identified in May as part of the initial Advisory Panel meeting.

Five candidate test fuels were selected for potential combustion test program use during the May 24<sup>th</sup> Advisory Panel meeting (refer to Table 1). From these five it is desired to select three for test program use representing each of the following categories: (1) a low reactivity bituminous coal (~25% VM), (2) a subbituminous coal, and (3) a high reactivity bituminous coal (~35% VM).

Final selection of the three test fuels will be made pursuant to the outcome of proposed test facility permit modifications to increase the maximum permitted ash loading above the present limit of 10.9 lb-ash/MMBtu @ 50 MMBtu/hr (9.1 lb-ash/MMBtu @ 60 MMBtu/hr), and the outcome of bench scale reactivity testing of the Ashland and Bradford coals to determine which is best suited for use as the low reactivity bituminous test coal.

**Table 1 – Candidate Large Pilot Scale Combustion Test Fuels**

Identification	Ashland	Somerville	Viking 1	Dave Johnston PRB	Bradford
Chemical Analyses					
VM	25.8%	33.6%	35.8%	29.5%	23.5%
FC	63.0%	41.7%	43.5%	34.5%	56.1%
FC/VM	2.44	1.24	1.22	1.17	2.39
HHV, BTU/lb	13,506	10,876	11,737	8,150	12,263
LHV, BTU/lb	13,099	10,311	11,139	7,512	12,188
Moisture	1.7%	14.5%	14.1%	31.2%	6.9%
Hydrogen	4.0%	4.2%	4.6%	3.1%	
Carbon	76.6%	59.4%	64.0%	48.4%	
Sulfur	0.8%	3.1%	2.3%	0.4%	1.9%
Nitrogen	1.2%	1.2%	1.0%	0.6%	
Oxygen	6.3%	7.4%	7.2%	11.4%	
Ash	9.6%	10.2%	6.7%	4.9%	13.5%
Total	100.2%	100.0%	100.0%	100.0%	22.3%
HGI	65				
Q/N	5.3	6.1	6.9	18.1	
lb N/MMBTU	0.89	1.10	0.89	0.77	0.00
lb S/MMBTU	0.59	2.87	2.00	0.52	1.52
lb Ash/MMBTU	7.1	9.4	5.7	6.0	11.0

**Task 2.2 – Low NO<sub>x</sub> Pyrolysis Burners**

- A draft layout of the main windbox compartment nozzles arrangement and separated overfire air elevations for use in the large pilot scale testing will be generated in May.

A draft layout of the main windbox compartment nozzle arrangement (Figure 1) and separated overfire air elevations (Figure 2) have been made in preparation for the large pilot scale combustion test. As shown,

the main windbox includes three elevations of coal and associated secondary, bottom end, and close coupled overfire air (CCOFA) compartments. Flexibility in operation has been provided with regard to compartments that are in-service in order to allow testing over a range of main burner region stoichiometries, and the evaluation of various auxiliary, CFS and bottom end air compartments configurations, while maintaining main windbox jet velocities.

Main Windbox
X
X
CC OFA
Coal
CFS
Aux
CFS
Coal
CFS
Aux
CFS
Coal
Bottom
Bottom
X
X

**Figure 1 – Draft Large Pilot Scale Combustion Test Facility Main Windbox Layout**

With regard to the separated overfire air (SOFA) system design (Figure 2) it is expected that two elevations of SOFA will be used for the combustion testing, consistent with the design of commercial TFS 2000™ R type low NO<sub>x</sub> firing systems. The final locations of the SOFA compartments will be designed to allow testing over a range of staged residence times representative of those expected for a typical TFS 2000™ R field retrofit.

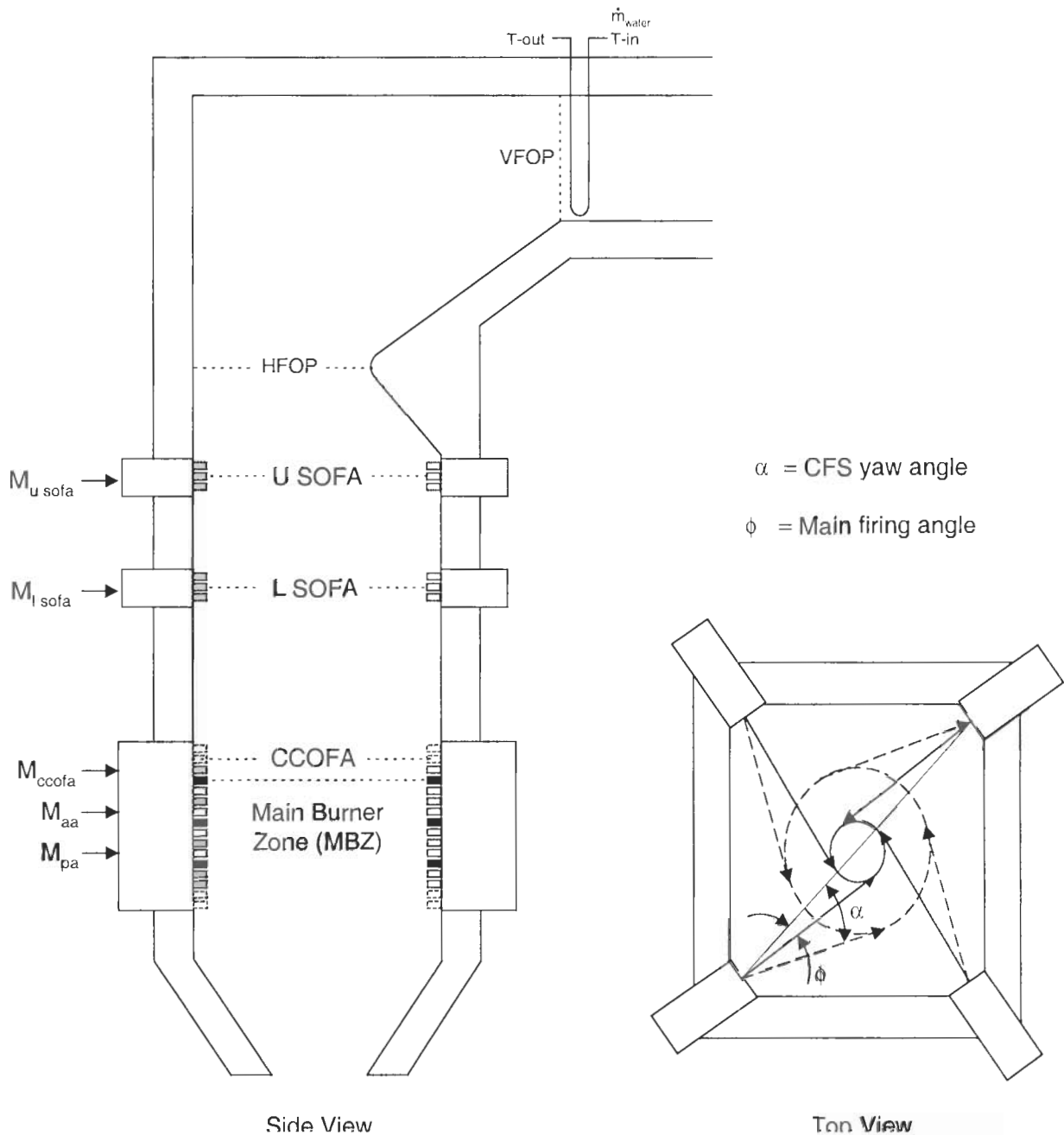


Figure 2 – DRAFT Large Pilot Scale Combustion Test Facility Overfire Air Configuration

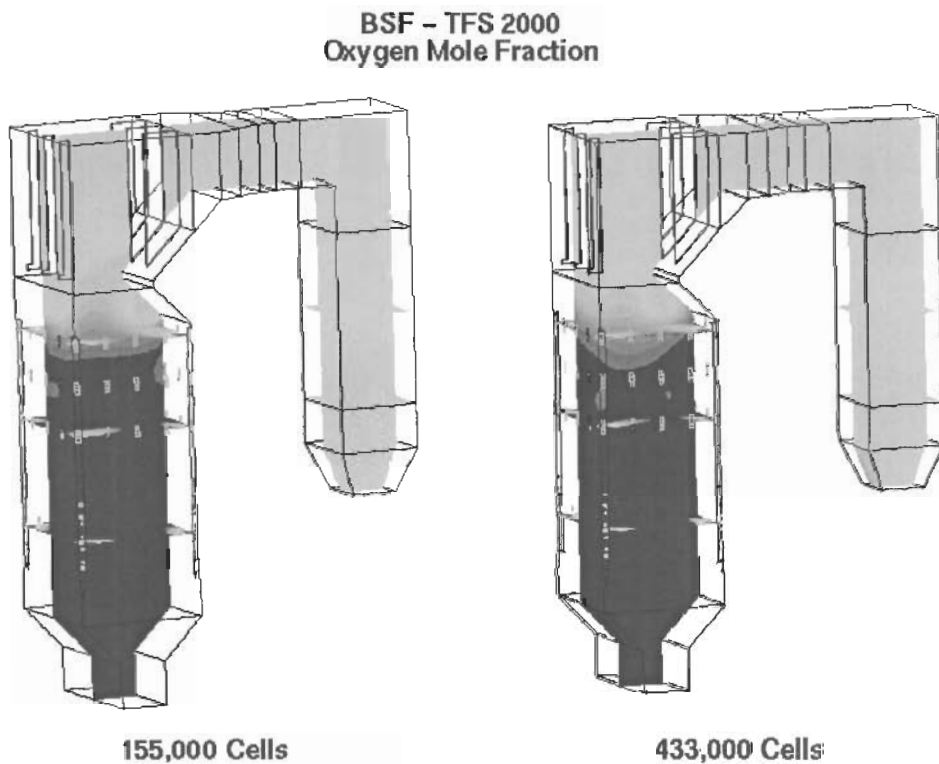
### Task 2.3 – Global Mixing Process Improvement

- *Evaluation of the two reduced run time modeling approaches will be completed in May. In addition, the SOFA modeling matrix will be finalized and parametric case runs initiated.*

As noted in the April month end report, two strategies were employed to decrease the CFD model simulation time required for the parametric global mixing process evaluations. First, a baseline simulation

using a coarse grid of 155,000 cells was run to compare the impact of grid size on the penetration and mixing of the separated overfire air (SOFA). The other approach was to generate a grid of the BSF starting at a plane between the main windbox outlet and the SOFA inlets. Then, the boundary conditions of the large baseline case were patched into the inlet of the smaller, upper furnace only model. This approach resulted in a more detailed model of the upper furnace that is approximately 1/2 the size of the full baseline model.

To determine the efficacy of the various modeling approaches, cases were run in May for a TFS-2000™ condition with both a low and a high SOFA velocity condition using both models. Similar trends in SOFA mixing were observed between the two techniques. Although the refined grid in the SOFA region associated with the 1/2 boiler model may enhance the quantitative accuracy of the numerical predictions, it was decided to use the coarse grid, full furnace model as the CFD matrix includes variations in bottom end air and coal type that can not be modeled with the 1/2 boiler approach.



**Figure 3 – BSF Oxygen Concentration: Elevation View**

BSF – TFS 2000  
Oxygen Mole Fraction  
Lower SOFA Elevation

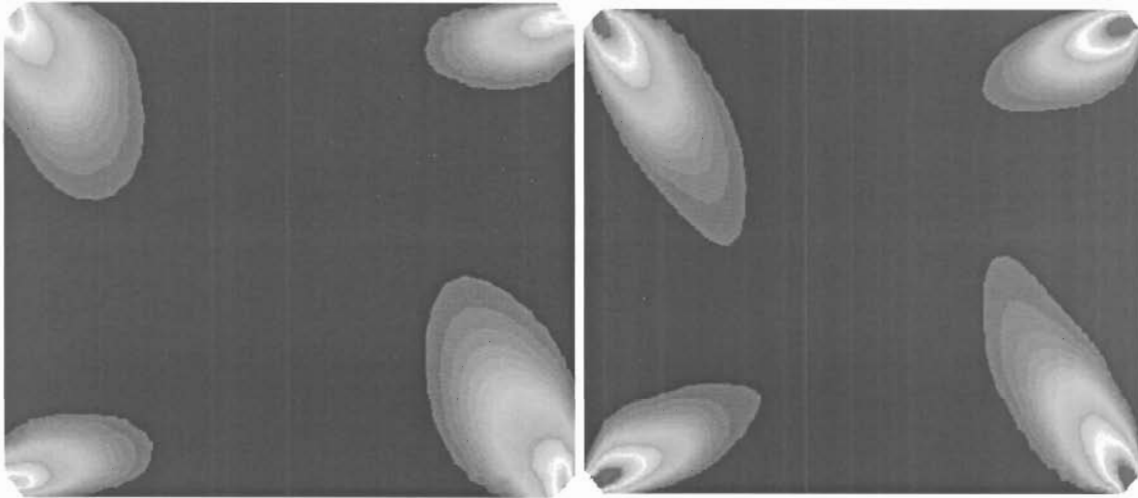


Figure 4 – BSF Oxygen Concentration: Lower SOFA Plan View

BSF – TFS 2000  
Oxygen Mole Fraction  
Upper SOFA Elevation

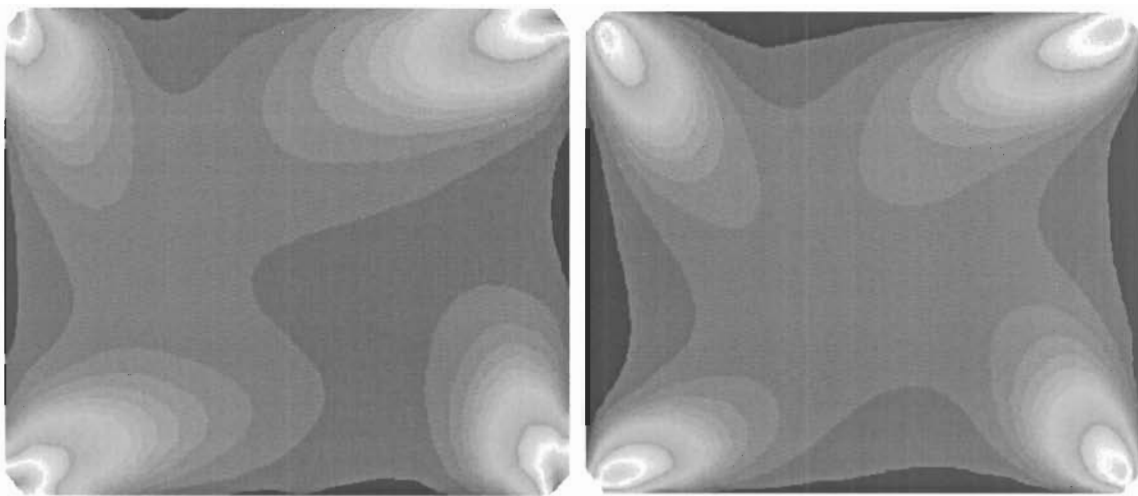


Figure 5 – BSF Oxygen Concentration: Upper SOFA Plan View

Figures 3, 4 and 5 compare the effect of grid size for CFD simulations of the BSF configured with the TFS 2000<sup>TM</sup> firing system. As illustrated in the figures, the predicted temperature and species distributions are quite similar for the two cases. There is, however, a small impact of the grid on the predicted penetration of the overfire jets. As expected, the OFA jets diffuse more rapidly as the grid resolution is decreased for the coarse grid model. However, the predicted trends in mixing as a function of OFA velocity and location

were consistent between the grids and did not justify the additional CPU time needed to solve the case with the finer mesh grid.

With regard to the parametric cases, a matrix was generated containing 16 CFD cases to be run as part of the global mixing task. Variables to be investigated include SOFA velocity (nominal, high and low), nozzle location (corner or wall), number of SOFA elevations (1 or 2), quantity of bottom end air, and coal type (bituminous or sub-bituminous).

A new, coarse mesh grid was generated using the firing system configuration that is planned to be tested in the first combustion test period of this project (refer to Task 2.2). All currently planned parametric runs will utilize this grid / firing system design.

#### **Task 2.4 – Advanced Control System Design**

- *Secondary approaches to obtain data for neural net model development will be investigated*

Several secondary approaches to obtain data for neural net model development were reviewed in May. Among the options, two were selected to support this work. The first is to await performance of the large pilot scale testing and resultant data as a means to obtain required addition data for use in developing a neural net model for control over and optimization of critical process parameters associated with an integrated ultra-low NO<sub>x</sub> system. The second is to actively seek opportunities to participate in the evaluation of commercially installed neural net systems under separate (internal) funding. If secured, this option will compliment the large pilot facility test program work by providing data at an increased scale and with the added process complexity associated with a commercial pulverized coal fired utility boiler.

- *Continue MatLab / Simulink air and fuel flow balancing controller modeling*

Additional MatLab / Simulink modeling activities in support of the design of the air and fuel flow balancing controllers was performed in May.

- *Complete engineering design of fuel and air flow control system for large pilot scale testing*

Engineering design of the fuel and air flow control system has been postponed pending finalization of the 1:1 transport air: fuel system design (see project Milestone 6 below).

- *Procure carbon in ash sensor system materials*

Purchase of the carbon-in-ash equipment has been suspended pending resolution of issues associated with designing an instrument small enough for use the large pilot test facility. The originally selected commercial instrument, ABB's Carbon in Ash analyzer is not available in an appropriate size for BSF test use. As a result other, commercially available instrumentation and approaches are being explored along with possible options to fabricate a purposely constructed "test" instrument in support of the large pilot work.

In addition, all major material items have been received for upgrade of the large pilot scale test facility control system. Graphical interface and environment conversion is underway and installation, reconfiguration of DCS Software and switch-over to the new system is planned for late June - early July for this project related, internally funded activity.

#### **Task 3.1 – Test Planning & Facility Preparation**

- *Pursuant to Milestone #5, General Test Facility Preparation, check-out of the BSF plumbing / mechanical and electrical systems will be completed in May.*



Approximately 80% of the planned General Test Facility Preparation activities were **completed** in May, consistent with the intent of the work plan. Additional, substituted activities including **repair of the large, painting of the main facility windboxes** resulted in large part for the noted delay.

The **remaining** 20% of the General Test Facility Preparation work will **be completed** in June.

A breakdown of the individual facility preparation work accomplishments **for May** is as follows:

Plumbing / Mechanical	% Completed
- Remove rust accumulation from the BSF hopper bottom,	100
- Complete the integrity testing of the "V – Hopper,"	50
- Refurbish waterbed compartments,	85
- Remove, clean, & lubricate the 18" secondary air windbox dampers,	100
- De-scale the windbox plenums & compartment ducting,	100
- <b>Inspect and lubricate main windbox compartment dampers,</b>	100
- <b>De-slag BSF water jacket ports for next "hydo-test,"</b>	100
- Initiate the replacement of the superheater division panel tubes,	100
- Inspect the main secondary air flow ducting (FD fan to BSF),	0
- Inspect all air & water utility plumbing systems,	50
- Inspect the coal transport lines,	40
- Cleaning the coal feeder (Thayer) & housing in preparation for future maintenance,	100
Electrical	
- Test individual <b>DCS</b> I/O blocks,	100
- Test main <b>power</b> circuits to BSF / related equipment,	100
- Inspect / operate <b>electronic dampers</b> (air heater, and secondary air flow control)	100
- <b>Inspect / operate</b> facility fans (FD & ignitor)	50
- Schedule vendor for direct fired air heater (Maxon), coal feeder (Thayer) and soot blower maintenance / check-out	100

#### Task 4 – Carbon Burnout System Evaluation

- *The field unit for CBO™ cost / performance evaluation will be selected. In addition, preliminary CBO™ cost and performance data will be transferred from Progress Materials to U.S. Power Plant Laboratories.*

No activity occurred on the CBO™ evaluation task in the month of May. The noted work scope will be performed in June and July, 2000.

#### Task 5 – Engineering Systems Analysis & Economics

- *Continued development of a preliminary cost comparison between various low NO<sub>x</sub> control systems will be performed. Design parameters for the systems will be developed. Methodology for economic analyses will be proposed.*

Work continued on the development of a preliminary cost comparison between various ultra-low NO<sub>x</sub> control systems. In addition, a presentation on the scope of this work was made to the Utility Advisory Panel during the May 24<sup>th</sup> meeting. At that time, discussions were held on economics and methodology to be used for cost comparison. Plant performance factors that will be determined in the course of the

analysis were identified. The economic comparison will be made comparing Cost of NO<sub>x</sub> removed (\$/Ton), Cost of generating power (\$/kWh), and Net Present Value ( \$) between the systems. An in-house developed proprietary economic model will be used to perform economic comparison. Variations in this approach with that of EPRI's TAG model will be reviewed to ensure a consistent approach is used.

#### Task 6 – Advisory Panel

- The first advisory panel meeting will be held in Windsor, CT on May 24, 2000.

The first meeting of the Utility Advisory Panel was held in Windsor, CT on May 24, 2000. Attendees to the meeting included:

Ian Andrews	PacifiCorp
Gary Camody	Alstom Power Performance Projects
Woody Fiveland	Alstom Power U.S. Power Plant Laboratories
Bob Hilton	Alstom Power Environmental Systems
Bill Hocking	Alstom Power U.S. Power Plant Laboratories
Soung Kim	United States Department of Energy
Robert Lewis	Alstom Power Performance Projects
Charles Maney	Alstom Power U.S. Power Plant Laboratories
John Marion	Alstom Power U.S. Power Plant Laboratories
Jerry Piskowski	Indianapolis Power & Light
Galen Richards	Alstom Power U.S. Power Plant Laboratories
Chris Smith	Alstom Power Performance Projects
Jerry Urbas	Reliant Energy

Covered topics included an overview of the project and resulting technologies, and discussion of the engineering systems analysis / economic case study task work scope. In addition, preliminary selections of the test fuels (refer to the discussion of Task 2.1 – Test Fuels Characterization) and case study field units were made. Minutes from the first advisory panel meeting are contained in an MS Word document entitled "MeetingMinutesUAP.doc" transmitted separately.

#### WORK PLANNED FOR NEXT REPORTING PERIOD:

##### Task 2.1 – Test Fuels Characterization

- Samples of the candidate low reactivity bituminous coals will be obtained and characterization work will be initiated in June.

##### Task 2.2 – Low NO<sub>x</sub> Pyrolysis Burners

- Proposed, draft overfire air elevation locations will be compared with that of typical, existing field units in order to enable a final selection to be made.

##### Task 2.3 – Global Mixing Process Improvement

- Eight of the 16 parametric runs to evaluate global mixing will be completed in June. In addition, a user-defined function to calculate the degree of mixing for a given SCFA arrangement will be developed. Finally, chemical kinetic modeling to investigate / evaluate the high temperature SNCR process will be begun.

- Complete investigation of secondary approaches to obtain data for neural net model development including identification of candidate (field) source units.
- Continue MatLab / Simulink air and fuel flow balancing controller modeling
- Complete engineering design of fuel and air flow control system for large pilot scale testing and procure additional needed materials. This involves designing cost effective modifications that may improve the usefulness of BSF test data for neural net modeling as well as making balancing tests easier to perform.
- Identify approach(es) to address on-line carbon in ash analysis needs.

### Task 3.1 – Test Planning & Facility Preparation

- Pursuant to project Milestone #5, General Test Facility Preparation, check-out of the BSF plumbing / mechanical and electrical systems will be completed by the revised date of June 30. Remaining, planned work associated with this activity includes:

Plumbing / Mechanical	% Completed
-----------------------	-------------

- |  |    |
|--|----|
| - Complete the integrity testing of the "V – Hopper,"              | 50 |
| - Complete the refurbishment of waterbed compartments,             | 85 |
| - Inspect the main secondary air flow ducting (FD fan to BSF),     | 0  |
| - Complete inspection of all air & water utility plumbing systems, | 50 |
| - Complete inspection of the coal transport lines                  | 40 |

#### Electrical

- |  |    |
|--|----|
| - Complete inspection / operate facility fans (FD & ignitor) | 50 |
|--|----|

In addition, the following combustion test facility preparation work will also occur in June:

#### Plumbing / Mechanical

- Check coal line orifice spools,
- Schedule sootblower maintenance,
- Reinstall superheater tube-banks,
- Continue BSF water-jacket hydro testing,
- Reinstall combustion air dampers,
- Inspect coal feed silo systems operation,
- Order required flexible coal piping,
- Inspect / repair main water control valve.

#### Electrical

- Service / calibrate pulverized coal feeder,
- Upgrade direct fired air heater burner,
- Refurbish individual windbox compartment flow devices,
- Install remote I/O for new DCS,
- Select flame scanner hardware,
- Determine action with regard to on-line carbon in ash measurement.